IMPACT OF WASTE INPUTS ON THE QUALITY OF THE AVON RIVER

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Ministry of the Environment

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ON THE QUALITY
OF THE AVON RIVER

Water Resources Assessment Unit
Technical Support Section
Southwestern Region

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SUMMARY AND RECOMMENDATIONS

The 1975 Thames River Basin Water Management Study recommended that the City of Stratford should not increase its waste loadings to the Avon River. At that time, the Ministry of the Environment (MOE) placed restrictions on further subdivision approvals. A study completed in 1977 provides a basis for the type of abatement measures required to improve water quality in the Avon River recognizing that additional development pressures exist within the basin.

Agricultural runoff was found to represent 47 percent of the total annual phosphorus load (14,700 kilograms, equivalent to 32,300 lbs.) and the Stratford sewage treatment plant 35 percent of the total phosphorus load. The elevated phosphorus concentrations in the Avon River have caused luxuriant growth of aquatic plants from Stratford to the North Thames River, estimated to have a minimum annual average biomass production of 330,000 kg (727,500 lbs). The photosynthesis and respiration of the aquatic plants have caused widely fluctuating dissolved oxygen conditions in the river and all stations from Stratford to the mouth of the Avon have exhibited minimum dissolved oxygen levels less than the MOE objective of 4 milligrams per litre (mg/l).

P cause biomass growth, cause low DO.

Concentrations of zinc and chromium in the Avon River downstream from Stratford were measured in excess of the MOE guidelines for the protection of aquatic life. Industrial discharges to storm sewers accounted for 66 percent of the zinc loading to the Avon River.

The estimated annual chromium load to the Avon River from the Stratford sewage treatment plant (which includes some industrial inputs) and industrial discharges to storm sewers is 3,680 kg (8,100 lbs). It is unknown how much of the chromium load from the Stratford sewage treatment plant originates from industrial sources.

This study indicates that chlorine residual is lethal to fish life for at least 500 feet downstream from the Stratford sewage treatment plant during low-flow periods. The Stratford sewage treatment plant also contributes 72 percent of the annual ammonia load to the Avon River which, combined with industrial discharges (22 percent), has elevated ammonia levels above the MOE objective of 0.02 mg/l un-ionized ammonia.

Even though water quality objectives for five parameters were not met during the 1977 field survey and recommended phosphorus concentrations were exceeded by a factor of 10, improved pollution control measures in the City of Stratford have resulted in improvements in bottom fauna and fish since 1959. Smallmouth bass were documented in the Avon River during the 1977 survey for the first time in 20 years.

Some of the water quality objectives for the Avon River such as chlorine residual, zinc, chromium and possibly ammonia can likely be met using appropriate abatement measures. Others such as the recommended phosphorus concentration of 0.03 mg/l and the minimum dissolved oxygen objective during the spring-to-fall period may not be met in the foreseeable future because of current limitations on pollution abatement measures both for agricultural runoff and municipal sewage treatment. The improved bottom fauna conditions and the increase in diversity of fish populations downstream from Stratford have provided evidence of this improvement in water quality.

In light of these positive responses to pollution abatement measures, the long-term objective should be to reduce phosphorus loadings to the Avon River. The following recommendations will improve water quality in order that urban and rural development may proceed in harmony with the aquatic life and water uses throughout the Avon River watershed:

1. Chlorine residual in the reach downstream from the Stratford sewage treatment plant should be reduced below the toxic level for aquatic life. This could be achieved by eliminating chlorination, using another type of disinfection or chlorination followed by dechlorination.

2. Industrial waste effluents to storm and sanitary sewers should be controlled in order that the MOE's objectives for chromium and zinc in the Avon River can be met during low flow conditions. Ammonia from industrial effluents gaining access to the Burritt Street storm sewer should be reduced in order to meet objectives to protect aquatic life.

3. Agricultural practices to reduce the total phosphorus load to the river should be implemented in the Avon River watershed. Recent studies indicate that agricultural runoff is the major contributor of sediment to streams in Southwestern Ontario and since total phosphorus is associated with sediment particles, agricultural runoff is also a major contributor of phosphorus. Feasible remedial measures to control pollution from agricultural runoff (phosphorus, sediment and bacteria) are outlined in the International Reference Group on Great Lakes Pollution From Land Use Activities (PLUARG) report to the International Joint Commission (IJC) on "Summary Pilot Watershed Report Grand River Basin, Ontario". The following excerpt from the above-mentioned report contains recommendations to control agricultural runoff:

   "The reduction of erosion rates can be realized by various control strategies to maintain soil structure (i.e. minimum tillage methods) and the use of cover crops to lessen the erodibility of soil from the impact of rain. Other alternative strategies such as contour

cropping, diversion terraces, etc., will reduce the transport of eroded soil into the drainage channel. Field borders (i.e. buffer strips of vegetation on the drainage way) will reduce the velocity of runoff water and the amount of material that can be held in suspension. Restriction of livestock access to streams during periods of high soil moisture will reduce the incidence of streambank instability and subsequent slumping of materials into the stream.

Excessive fertilizer and manure applications can elevate natural nutrient levels in the streams which drain areas of active fertilization. Proper use of fertilizer and manure for optimum crop production and plant growth should be encouraged (i.e. immediate plow down). Runoff or seepage from manure sewage or livestock feeding areas should be discouraged. Restriction of livestock access and defecation in the streams may be necessary in some areas to reduce both nutrient and bacterial contamination from livestock."

4. A program to define hydrologically active areas as outlined in the recent Progress Report of the Thames River Implementation Committee should be carried out in order to determine the land areas contributing most significantly to pollution of the Avon River in order that remedial measures could be carried out in these areas first. After the cost benefits of implementing various remedial measures have been established, a co-ordinated program to reduce pollutants from agricultural runoff should be carried out through the combined efforts of the Upper Thames River Conservation Authority and the Ministry of Agriculture and Food.

5. The Stratford Sewage Treatment Plant should be upgraded in order to reduce ammonia in the effluent during low streamflow periods. Concentrations of un-ionized ammonia in the Avon River downstream of the Stratford

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sewage treatment plant should be reduced to meet the MOE objective of 0.02 mg/l for the protection of aquatic life.

6. Since past waste control measures (particularly phosphorus removal) have shown an improvement in biota in the Avon River, further reductions in phosphorus at the Stratford sewage treatment plant should be accomplished to yield additional improvements.

   Phosphorus removal could be enhanced by the reduction of sewage plant by-passing, either by plant expansion or increased storage at the plant and reduced infiltration to sanitary sewers. An improved monitoring program of sewage plant by-passing should be implemented in order to obtain a better estimate of the magnitude of this load. Further reductions could be attained by increased chemical additions at the sewage treatment plant. All possible measures to reduce phosphorus in the sewage effluent should be considered.

7. Even though minimum dissolved oxygen concentrations may not meet the MOE objectives on the Avon River during the late spring-to-fall period in the foreseeable future, measures should be taken to reduce the aquatic plant growth and thus the impact on dissolved oxygen and fish. It is suggested that the Upper Thames River Conservation Authority negotiate agreements with farmers owning land bordering the Avon River from Stratford to the North Thames River for reforestation efforts to provide increased shading of the Avon River, thereby reducing sunlight available to stimulate aquatic plant production.

8. The City of Stratford should review street sweeping practices in the City in order to determine if further reductions of the organic loadings (5-day biochemical oxygen demand or BOD_5) and lead loadings from storm sewer runoff could be accomplished. Other practices to reduce pollution inputs from urban runoff outlined in

the PLUARG report "Summary Pilot Watershed Report Grand River Basin, Ontario" should be considered and the following is an excerpt from that report:

"Sediment and sediment-associated contaminants are the most serious problems requiring control in urban runoff. The following measures should be assessed to determine their effectiveness in controlling pollution from urban runoff:

a. The use of mulches, sedimentation ponds, etc. to reduce sediment loadings due to erosion from urban construction sites.

b. The use of bank stabilization techniques to reduce sediment loads due to streambank erosion.

c. The reduction of atmospheric emissions which subsequently accumulate on impervious surfaces and are washed off during rainstorm or melt periods.

d. The initiation of public-education programs designed to reduce the accumulation of litter and animal waste on streets, and to promote the proper use of pesticides and fertilizers on residential property, would reduce the pollutant inputs of phosphorus, bacteria and pesticides from urban areas.

e. Improve collection and treatment systems and promote new storage and infiltration systems for urban storm runoff such as on-site storage of contaminants, porous pavement to promote infiltration, separation and recovery basins, traps, etc.

f. Reduce pesticides washoff from utility corridors and residential, recreation and agricultural lands.

g. Reduce washoff of accumulated bacterial contaminants (i.e. organic debris, animal excreta) from pervious surfaces and industrial point sources (i.e. food processing plants)."

9. The feasibility and possible implementation of measures to reduce phosphorus concentrations in the Avon River by in-stream treatment methods (such as a calcium carbonate filter dam and aquatic plant harvesting) warrants consideration.

INTRODUCTION

The 1975 Thames River Basin Water Management Study recommended that Stratford should not increase its waste loadings from all sources to the receiving stream. On the basis of this recommendation, the Ministry of the Environment placed restrictions on any further subdivision approvals in Stratford.

A detailed assessment of all waste inputs to the Avon River was necessary prior to making any decision on the types of pollution abatement that would be required to meet the recommendations in the 1975 Study and the MOE water quality objectives. The 1975 Study also recommended further investigations and/or pollution abatement measures for industrial discharges (including enforcement of sewer use by-laws), storm sewer runoff and agricultural runoff.

Several recommendations in the 1975 Thames River report pertained to remedial measures to reduce pollution from agricultural runoff. The Thames River Implementation Committee, established to implement the recommendations contained in the report, has outlined its stance towards the recommendations and has suggested an action program in the Committee's 1978 Progress Report. Measures such as control of fertilizer applications, strip cropping, crop rotation, grassed waterways, vegetative buffer zones and restriction of free access of livestock to streams were recommended to reduce pollution from agricultural runoff.

A study of the Avon River was carried out in 1977 to determine the magnitude of all waste inputs from urban, rural and industrial sources, to measure effects of these wastes on water quality and biota and to recommend a course of action to improve water quality. Two three-day surveys were conducted in June and July, 1977 which included the measurement of contaminants in industrial, sewage treatment plant, storm sewer and agricultural discharges. Agricultural

runoff loadings to the Avon River were established to determine the significance on water quality in relation to other waste inputs. Water quality in the Avon River was measured at 13 stations on the Avon River, based on sampling and analyses for heavy metals, ammonia, bacteria, chlorine residual, BOD_5, suspended solids and phosphorus. A special study on the effects and extent of impact of chlorine residual was included. In addition, four biological surveys were conducted from June to November, 1977 to document the types and biomass of aquatic plants in the Avon River from Stratford to the North Thames River. Fish collections were carried out on two occasions and macroinvertebrates were sampled on one occasion in July.

To afford historical comparison, biological and water quality information obtained since 1959 was used to compare with conditions in 1977. Information from PLUARG reports released in 1978 were used extensively to estimate waste loads. Unit area waste loads from the PLUARG report "Summary Pilot Watershed Report Grand River Basin, Ontario" were used to estimate waste loadings from urban runoff (storm sewers), wooded/idle land and agricultural runoff.

Difference between waste loading to lakes & to streams? Effects?

It is anticipated that implementation measures to reduce waste loadings from agricultural, municipal and industrial sources (particularly phosphorus and substances toxic to aquatic life) will be forthcoming. This report presents guidelines for abatement measures that will allow Stratford to have restricted development, reduce the erosion and pollution load from agricultural land and improve water quality and aquatic life in the Avon River.

WATERSHED CHARACTERISTICS

PHYSIOGRAPHY/GEOGRAPHY

The Avon River watershed is located in the upper Thames River Basin in Perth County. The City of Stratford is the only large municipality in the watershed, having a 1978 population of 26,500, and is situated at the centre of the drainage basin (Figure 1). The mean annual precipitation at Stratford is 991 millimetres (39 inches).

The Avon River watershed drains an area of 166 square kilometeres (km^2) which is equivalent to 64 square miles (sq. mi.). Rocks and cobble make up the stream bed downstream from Stratford and a clay-silt stream bottom prevails immediately upstream from Stratford.

The upper Avon River watershed (upstream from Brocksden) is in the Waterloo Hills minor physiographic region. The surface material is composed of sandy hills, some of which are ridges of sandy till while others are kames or kame moraines, with outwash sands occupying the intervening hollows. The watershed downstream from Brocksden is located on the Stratford till plain. The lower basin is in a broad clay plain and the main channel follows a narrow spillway along its entire route.

HYDROLOGY

The Avon River drains an area of 166 km^2 (64 sq. mi.) and is characterized by high spring runoff conditions and low streamflows during the summer and fall periods. For purposes of this study the watershed area was subdivided into two sub-basins, with the upper basin representing the area above Station 8 (at the Lorne Avenue storm sewer) which drains 111 km^2 (43 sq. mi.). This upper sub-basin was used to calculate the annual waste loadings to the Avon River

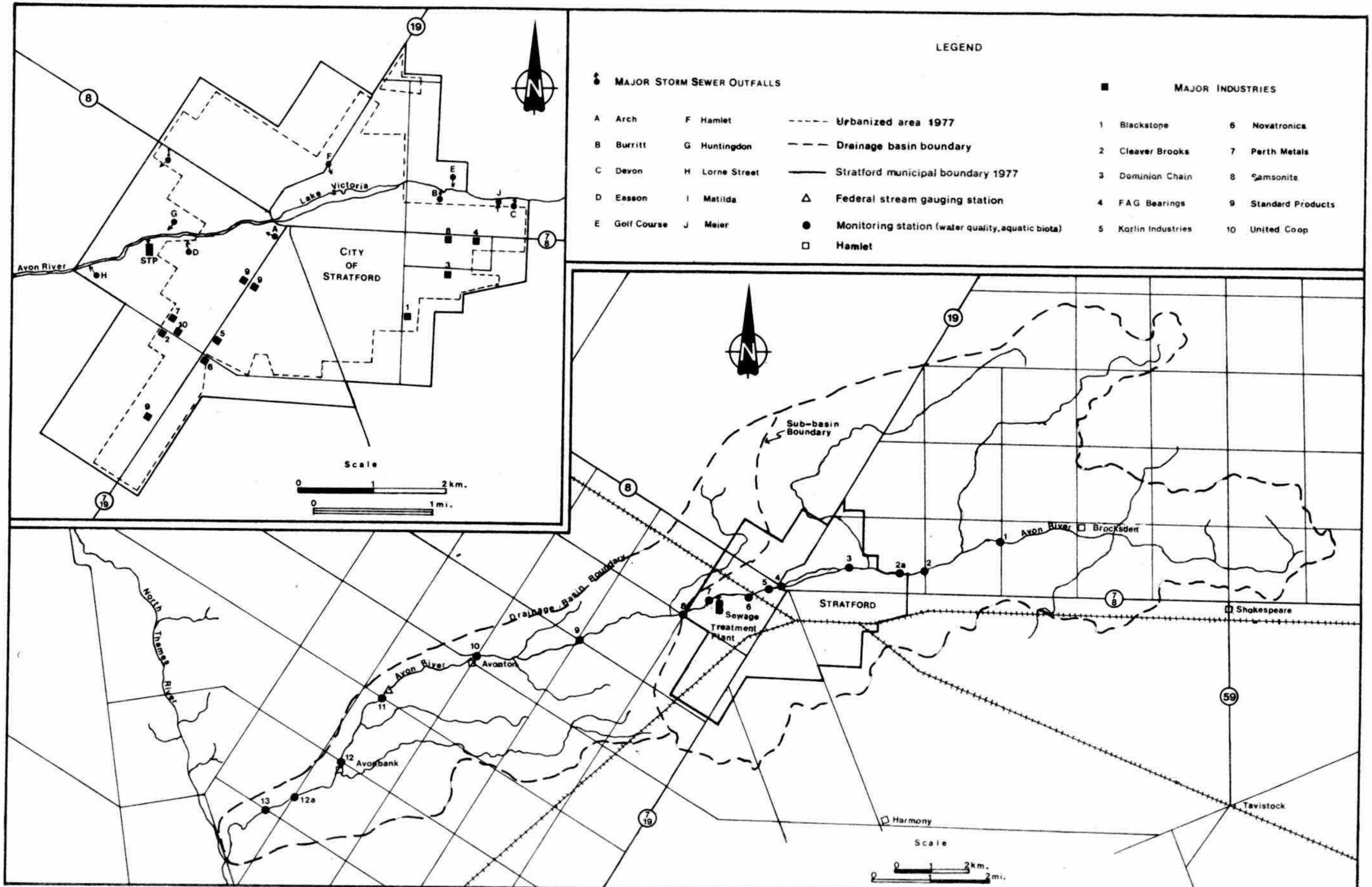

Figure 1. Monitoring stations in the Avon River watershed, 1977.

from all sources upstream from Station 8. The drainage area of the Avon River downstream from Station 8 was used to show the effects of waste contaminant loadings on water quality and biota.

The pro-rated mean annual streamflow at Station 8 is 1.56 cubic metres per second (m^3/sec), equivalent to 55.8 cubic feet per second (cfs). Streamflow data are available at Federal Stream Gauging Station 02GD018 on the Avon River between Avonbank and Avonton (Figure 1). The mean monthly streamflows and minimum monthly average flows with a 1-in-10 year return period (as pro-rated from the Federal Gauge) for the Avon River at the Lorne Avenue storm sewer (Station 8) are presented in Table 1 (streamflows include the effluent from the Stratford sewage treatment plant). The highest monthly average flow occurs in March. During the June-to-October period streamflow may be minimal at times and most of the flow during dry periods is from the Stratford sewage treatment plant. It is believed that natural streamflow is sustained throughout most years on the Avon River upstream from Stratford as a result of base flow associated with gravel deposits in the Shakespeare area.

The average streamflows at Station 8 for the June 19-22 and July 18-21, 1977 surveys were 0.36 m^3/sec (12.9 cfs) and 0.31 m^3/sec (10.9 cfs), respectively. The dilution ratio of streamflow to sewage effluent at the time of both surveys was about 1 to 1. During the June survey, flows were reduced by approximately 0.14 m^3/sec (5 cfs) between Station 8 and Station 10. Reductions of about 0.085 m^3/sec (3 cfs) were noted on July 20, 1977 over the same reach, indicating movement of water into the permeable substrate may be occurring.

Table 1. Estimated monthly streamflow for the Avon River downstream from Stratford at Station 8.[a,c]

Month	Mean monthly streamflow m^3/s (cfs)	Minimum monthly average streamflow with a return period of 1-in-10 years[b]. m^3/s (cfs)		Mean monthly 1976-1977 sewage flows m^3/s (cfs)	
January	1.59 (56)	0.45 (16)		0.16 (5.8)	
February	2.01 (71)	0.42 (15)		0.18 (6.4)	
March	4.45 (157)	2.18 (77)		0.37 (13.0)	
April	3.57 (126)	1.02 (36)		0.23 (8.1)	
May	1.13 (40)	0.54 (19)		0.16 (5.8)	
June	0.62 (22)	0.37 (13)		0.14 (4.9)	22%
July	0.42 (15)	0.25 (9)		0.14 (4.8)	33%
August	0.40 (14)	0.25 (9)	50%	0.14 (5.0)	35%
September	0.54 (19)	0.17 (6)		0.25 (8.8)	50%
October	0.74 (26)	0.17 (6)	100%	0.21 (7.5)	30%
November	1.95 (69)	0.54 (19)	30%	0.23 (8.2)	
December	1.59 (56)	0.54 (19)		0.23 (8.2)	
Annual	1.58 (55.8)			0.19 (6.7)[c]	

a - Streamflow data is pro-rated from the federal gauging Station 02GD018.
b - Flows include sewage discharges.
c - Period of record is 1965-77.
- Drainage basin area upstream from Station 8 is 111 km^2 (43 sq. mi.).

WATER USE

Outside of the City of Stratford the land use in the River basin is predominantly agricultural. Cattle watering is significant along the Avon River both upstream and downstream from Stratford. Recreation is essentially limited to the City of Stratford which has several park areas along the Avon River, although there is an Avon Trail Association which has a hiking trail through Stratford and the upper watershed area.

There are 10 licenced commercial bait operators who collect bait fish on the Avon River downstream from Stratford, particularly in the lower reaches near the North Thames River. Assimilation of municipal and industrial wastes from the City of Stratford is an important use of the lower portion of the river.

WASTE CONTAMINANT LOADS TO THE AVON RIVER WATERSHED AT STRATFORD

The 1975 Thames River Basin Water Management Study determined that the water quality in the Avon River downstream from Stratford does not meet MOE objectives for dissolved oxygen. The study also pointed out that "Such constituents as chloramines, phenols and heavy metals may never be completely removed and even low levels of these components assume significance when essentially no dilution is afforded by the receiving stream during low flows".

The total annual load of individual waste contaminants to the Avon River upstream from Station 8 was determined by adding the annual estimates for urban and rural inputs. The former included storm sewer runoff, the Stratford sewage treatment plant discharge and industrial discharges, whereas rural inputs were based on intensive agricultural land runoff and wooded/idle land runoff (Table 2). The storm sewer runoff loads from the City of Stratford were determined by using general unit area loads from the PLUARG report "Summary Pilot Watershed Report Grand River Basin, Ontario". The unit area loads from the Grand River were multiplied by the area of urbanized development (including park areas) as outlined in Figure 1. The urbanized area of Stratford is 11.7 km^2 (4.5 sq. mi.) and the total area within the City's municipal boundaries is 19.4 km^2 (7.5 sq. mi.). The loads from the Stratford sewage treatment plant were calculated from flow data for 1976 and 1977 and effluent analyses from plant records obtained from 1974 to 1977. The estimates for BOD_5, suspended solids, phosphorus and free ammonia included a partial accounting of sewage plant bypassing. The heavy metal loads were calculated from 1977 sewage plant flows and the July, 1977 water quality survey concentrations. Industrial discharges to the Avon River were determined from measured discharges to storm sewers during the 1977 surveys. Using the unit area loads from the PLUARG Grand River Study, the agricultural runoff and wooded/idle runoff were calculated

Table 2. Estimated average annual contaminant loads to the Avon River for selected parameters at the Lorne Avenue storm sewer (Station 8) downstream from Stratford.

Parameter	Storm sewer runoff %	Stratford sewage treatment plant %	Industrial discharges to the Avon River %	Agriculture runoff %	Wooded/Idle runoff %	Total contaminant loading kg (lbs.)
Total phosphorus as P	11	35	6	47	1	14,700 (32,300)
Soluble phosphorus as P	2	59	1	37	<1	4,200 (9,380)
Suspended solids	22 much higher in the summer period	<1	<1	76	2	5,770,000 (12,700,000)
BOD_5	35	17	13	← 35 →		168,000 (370,000)
Free ammonia as N	<1	72	22	← 5 →		44,700 (98,400)
Lead	61	-	19	16	4	770 (1,690)
Copper	10	13	50	22	5	1,000 (2,230)
Zinc	5	21	66	7	1	11,000 (24,200)
Chromium	-	92	8	-	-	3,680 (8,100)
Chlorine residual	0	100	0	0	0	1,800 (3,960)

- loadings not available

using areas of 76.6 km^2 (29.6 sq. mi.) and 23.0 km^2 (8.9 sq. mi.) respectively. BOD_5 and free ammonia loads for agricultural and wooded/idle runoff were provided using regular monitoring data from nearby agricultural watersheds.

The resultant annual waste contaminant loads depicted in Table 2 indicate that agricultural runoff and Stratford's sewage treatment plant discharges contribute 82 percent of the total annual phosphorus and 92 percent of the soluble phosphorus. Phosphorus is considered to be the key nutrient promoting excessive aquatic plant growths in the lower Avon River, thus causing depletion of dissolved oxygen (by night-time respiration of plants) below that required for healthy fish life.

Stratford's sewage treatment plant discharges 100 percent of the chlorine residual, 72 percent of the ammonia and 92 percent of the measured contributions of chromium to the Avon River upstream from Station 8. These substances are toxic to aquatic life at low concentrations and are the principal contaminants affecting fish life in the initial reach downstream from the sewage treatment plant to Station 8. The chromium in the sewage plant effluent probably originates from industrial discharges to the sanitary sewers in the town, although this has not been confirmed.

During the July, 1977 survey the sewage treatment plant discharge and industrial discharges accounted for 90 percent of the organic load (BOD_5) to the Avon River. This would put additional stress on fish by removing oxygen from the water through oxidation of this waste material.

Industrial discharges to the Avon River via storm sewers account for 66 percent of the zinc and 50 percent of the copper loads to the river. Aquatic life is affected by low concentrations of these heavy metals.

Concentrations and loads of contaminants associated with industrial discharges to the City of Stratford's storm sewers during the June and July surveys in 1977 are presented in Table I in the Appendix. The concentrations and waste contaminant loadings are provided for free ammonia, total and soluble phosphorus, suspended solids and BOD_5. Based on an industrial survey, Blackstone Industrial Products Ltd. and Dominion Chain Co. Ltd. account for almost all of the free ammonia and total phosphorus loads, 86 percent of the suspended solids and 88 percent of the BOD_5 load. Since the 1977 survey, Dominion Chain Co. Ltd. has commenced discharging its effluent to the sanitary sewer system. It was determined from further survey work in 1979 that a marsh area upstream from the discharge from Dominion Chain Co. Ltd. and Blackstone Industrial Products Ltd. on the Burritt Street storm sewer contributes about 0.45 kg/day (1 lb./day) of ammonia and 0.03 kg/day (0.06 lbs./day) of total phosphorus. This is low compared to other discharges to the sewer.

Storm sewer runoff contributes 35 percent of the BOD_5 and 61 percent of the measured lead load to the Avon River. Lead is toxic to fish at low levels. The organic load to the river from storm sewers could oxidize and impose additional dissolved oxygen stress on aquatic life. Storm sewer runoff contributed an estimated 66 percent of the suspended material to the Avon River upstream from Station 8 in the May-to-September period, indicating the effect of summer rain storms in flushing pollutants from storm sewers. Suspended solids are responsible for transporting other pollutants to the stream.

Estimated seasonal loads for total and soluble phosphorus, suspended solids and BOD_5 are presented in Table 3. Using annual loads from Table 2 and calculating the area runoff for each season from streamflow records, seasonal waste contaminant loads were estimated. For comparison, the waste contaminant loads for these same parameters during the July, 1977 survey (a low streamflow period) are given in Table 3. The Stratford sewage treatment plant contributes a

Table 3. Estimated average seasonal waste loads to the Avon River for selected parameters at Station 8 (Lorne Avenue storm sewer) downstream from Stratford.

Parameter and seasonal period	Storm sewer runoff %	Stratford sewage treatment plant %	Industrial discharge to Avon River %	Agriculture runoff %	Wooded/Idle runoff %	Total loading kg (lbs.)
Total phosphorus as P						
May to September	9	42	9	39	1	4,070 (8,950)
October to November	11	35	8	45	1	1,700 (3,740)
December to February	11	34	5	49	1	3,560 (7,840)
March and April	13	30	3	53	1	5,310 (11,700)
July 1977 survey (daily)	<1	73	23	← 3 →		6.85 (15.1)
Soluble phosphorus as P						
May to September	2	69	2	27	<1	1,310 (2,880)
October and November	2	61	2	35	<1	493 (1,080)
December to February	2	64	1	33	<1	1,180 (2,600)
March and April	3	48	1	47	1	1,340 (2,950)

Table 3. continued

Parameter and seasonal period	Storm sewer runoff %	Stratford sewage treatment plant %	Industrial discharge to Avon River %	Agriculture runoff %	Wooded/Idle runoff %	Total loading kg (lbs.)
July 1977 survey (daily)	15	82	2	1		3.06 (6.73)
Suspended Solids						
May to September	66	3	3	23	5	436,000 (960,000)
October and November	22	<1	1	76	1	636,000 (1,400,000)
December to February	22	<1	1	76	1	1,440,000 (3,170,000)
March and April	22	1	<1	76	<1	2,360,000 (5,190,000)
July 1977 survey (daily)	5	25	37	← 33 →		165 (363)
BOD_5						
May to September	29	19	19	← 33 →		47,300 (104,000)
October and November	30	20	16	← 34 →		21,900 (48,200)
December to February	35	12	13	← 40 →		42,100 (93,000)

Is this means that estimate is accurate?

Table 3. continued

Parameter and seasonal period	Storm sewer runoff %	Stratford sewage treatment plant %	Industrial discharge to Avon River %	Agriculture runoff %	Wooded/Idle runoff %	Total loading kg (lbs.)
March and April	37	15	6	← 42 →		65,500 (144,000)
July 1977 survey (daily)	2	46	44	← 8 →		114 (251)

greater proportion of the total phosphorus load (42 percent) and the soluble phosphorus load (69 percent) during the May-to-September period. This observation is reinforced by figures for the July, 1977 survey when 73 percent of the total phosphorus and 82 percent of the soluble phosphorus was contributed from the sewage plant. This is the prime growing period for aquatic plants and algae and also the period when dissolved oxygen concentrations for aquatic life are less than that required for healthy fish life. During the spring period (March and April) approximately one-third of the total annual phosphorus load is contributed to the Avon River, agricultural runoff accounting for 53 percent of the total phosphorus and 47 percent of the soluble phosphorus. The significance of this input on water quality, algae and aquatic plant growth in the lower Avon River is unknown but it may contribute significantly to growth of aquatic plants during summer if the phosphorus becomes absorbed into sediments in the lower Avon River. It should also be noted that industrial sources contributed 23 percent of the total phosphorus load during the July, 1977 survey.

Concentrations and loadings of heavy metals in storm sewer runoff, industrial and sewage treatment plant discharges and the Avon River were measured during the June and July survey in 1977 (Appendix Table II). Of 10 storm sewers and drains surveyed in the vicinity of Stratford, the Burritt Street storm sewer provided the highest (and only significant) heavy metal loading to the Avon River. Blackstone Industrial Products Ltd. and Dominion Chain Co. Ltd. were the sources of heavy metals to the storm sewer. The Burritt Street storm sewer contributed a loading of 0.66 kg/day (1.46 lbs./day) of copper and 6.6 kg/day (14.6 lbs./day) of zinc. The Stratford sewage treatment plant contributed a significant chromium loading of 5 kg/day (11 lbs./day) and a zinc loading of 1.8 kg/day (4.0 lbs./day). As mentioned previously, Dominion Chain Co. Ltd. now discharges its effluent to the sanitary sewer system.

Of the five source categories for waste contaminants, historical waste loadings are available only for the Stratford sewage treatment plant. The historical concentrations and loadings of contaminants in the sewage plant effluent are presented in Table 4. Annual mean sewage effluent flows, BOD_5 and suspended solids loads are given for 1962 to 1978. Total phosphorus and free ammonia loads are given since 1971 and 1972, respectively. All loads are based on the measured quality and quantity of sewage plant effluent. Loading figures do not include a complete accounting of sewage by-passing because of insufficient data. Even though the recorded sewage treatment plant flows have doubled since 1962 to about 0.225 m^3/sec (4.3 million gallons per day (mgpd)) the annual BOD_5 waste contaminant loading has been reduced by about 25 percent and suspended solids by 40 percent. Since 1972, total phosphorus loadings to the river from Stratford's sewage treatment plant have been reduced from 27,000 kg/yr (59,800 lb/yr) to about 3,600 kg/yr (7,900 lb/yr), a reduction of 85 percent. During a study on the Avon River during August 16 and 17, 1960, ammonia concentrations in the Stratford sewage treatment plant outfall were measured to be about 11 mg/l. During the 1977 surveys, the ammonia concentrations in the plant effluent averaged approximately 1.5 mg/l with a maximum concentration of 4.3 mg/l.

Table 4. Historical concentrations and loads of contaminants measured in the Stratford sewage treatment plant effluent.

Year	Flow		BOD_5			Free ammonia as N			Suspended solids			Total phosphorus as P		
	m^3/s	(mgd)	mg/l	kg/yr	(lbs./yr)	mg/l	kg/yr	(lbs./yr)	mg/l	kg/yr	(lbs./yr)	mg/l	kg/yr	(lbs./yr)
1962	0.11	(2.10)	13	45,000	(99,600)				21	73,000	(161,000)			
1963	0.11	(2.12)	13	45,000	(99,600)				11	39,000	(85,100)			
1964	0.14	(2.72)	10	45,000	(99,300)				10	45,000	(99,300)			
1965	0.16	(3.13)	12	62,000	(137,000)				12	63,000	(137,000)			
1966	0.16	(3.07)	10	51,000	(112,000)				8	41,000	(89,600)			
1967	0.23	(4.35)	9	62,000	(137,000)				10	72,000	(159,000)			
1968	0.18	(3.40)	8	45,000	(99,300)				12	68,000	(149,000)			
1969	0.19	(3.60)	9	54,000	(118,000)				12	72,000	(158,000)			
1970	0.17	(3.22)	7	37,000	(82,300)				12	64,000	(141,000)			
1971	0.17	(3.25)	9	77,000	(107,000)				9	49,000	(107,000)	5.0	27,000	(59,300)
1972	0.19	(3.56)	7	41,000	(91,000)	4	24,000	(52,000)	9	53,000	(117,000)	4.6	27,000	(59,800)
1973	0.19	(3.60)	8	48,000	(105,000)	2	12,000	(26,300)	10	60,000	(131,000)	3.6	21,000	(47,300)
1974	0.20	(3.75)	6	37,000	(82,100)				9	56,000	(123,000)	0.9	5,600	(12,300)
1975	0.20	(3.90)	8	52,000	(114,000)	12	78,000	(171,000)	8	52,000	(114,000)	1.1	7,100	(15,700)
1976	0.20	(3.80)	6	38,000	(83,200)	5	32,000	(69,400)	5	32,000	(69,400)	0.5	3,100	(6,900)
1977	0.21	(4.00)	4	27,000	(58,400)	3	20,000	(43,800)	3	20,000	(43,800)	0.7	4,600	(10,200)
1978	0.23	(4.33)	5	36,000	(79,000)	4	29,000	(63,200)	6	43,000	(94,800)	0.5	3,600	(7,900)

Plate 1. Lorne Avenue storm sewer outfall to the Avon River in the City of Stratford.

Plate 2. Avon River upstream of Stratford at Station 1.

WATER QUALITY OBJECTIVES FOR AQUATIC LIFE AND WATER USE

Water quality objectives for rivers and lakes in Ontario are outlined in the Ministry of the Environment's publication "Water Management; Goals, Policies, Objectives and Implementation Procedures of the Ministry of the Environment, November, 1978". Objectives are based principally on the protection of fish and other aquatic life. Maximum permissible recommended bacterial levels for livestock watering are also given. Selected objectives for several chemical parameters which relate to water uses and protection of the warm water fishery and other aquatic life in the Avon River are presented in Table 5, including four heavy metals. Since the toxicity of ammonia is temperature and pH dependent and the dissolved oxygen requirement for warm water fish is temperature dependent, these objectives have been outlined on a monthly basis with corresponding estimated monthly pH and temperature information. A general guideline for total phosphorus of less than 0.03 mg/l to curtail excessive plant growth in the Avon River is applicable. Phosphorus inputs to the Avon River are considered more critical to excessive aquatic plant growths during the late spring to fall period.

The Ministry of the Environment recommends that for general farmstead uses of water, including drinking, other household uses, and handling of produce and milk, that water of a quality meeting the "Drinking Water Objectives" be used. Considering bacteriological parameters, it is indicated that total coliform, fecal coliform, fecal streptococcus groups and pathogens such as *Pseudomonas aeruginosa* should not be present in water used for human or animal consumption. The Ministry guidelines state that "animals may be able to tolerate a fairly high level of total dissolved solids or bacteria if they are accustomed to such levels, but may be unable to tolerate a sudden change from water with low dissolved solids or bacteria to waters with high dissolved solids or bacteria."

Table 5. Water quality objectives for the Avon River at Stratford.

Month	Temperature (°C)	pH at Station 8[a]	Free ammonia as N (mg/l)	Dissolved oxygen (mg/l)	Chlorine residual (mg/l)	Heavy metals (mg/l) Cu	Zn	Cr	Pb
January	0 - 5	7.9	1.7	7	0.002	0.005	0.030	0.1	0.025
February	0 - 5	7.9	1.7	7	0.002	0.005	0.030	0.1	0.025
March	10	7.6	2.2	5	0.002	0.005	0.030	0.1	0.025
April	15	8.2	0.4	5	0.002	0.005	0.030	0.1	0.025
May	20	8.3	0.2	4	0.002	0.005	0.030	0.1	0.025
June	25	8.5	0.1	4	0.002	0.005	0.030	0.1	0.025
July	25	8.2	0.2	4	0.002	0.005	0.030	0.1	0.025
August	25	7.8	0.5	4	0.002	0.005	0.030	0.1	0.025
September	20	7.8	0.7	4	0.002	0.005	0.030	0.1	0.025
October	15	8.0	0.6	5	0.002	0.005	0.030	0.1	0.025
November	10	7.9	1.1	5	0.002	0.005	0.030	0.1	0.025
December	5	8.0	1.4	6	0.002	0.005	0.030	0.1	0.025

[a] Data from long-term monitoring station 04-0013-025-2 from 1968 to 1972.

EFFECTS OF WASTE CONTAMINANTS ON WATER QUALITY AND BIOTA

SURVEY RESULTS - WATER QUALITY

In conjunction with the monitoring of storm sewer outfalls, industrial discharges and Stratford's sewage treatment plant effluent, several locations on the Avon River upstream and downstream from Stratford were monitored (Figure 1). One survey was carried out from June 19 to 22, 1977 and the other from July 18 to 21, 1977. Bacteriological and chemical samples were collected over a period of 72 hours, including night-time sampling. The chemical results presented in Tables 6 and 7 are an average of 12 samples and the bacteriological results are geometric means of 6 samples.

The surveys showed that nutrient concentrations were higher downstream from Stratford than upstream. In general, total phosphorus concentrations were equal to or greater than the recommended level to prevent excessive aquatic plant growth at all stations monitored. Phosphorus concentrations downstream from the sewage treatment plant were almost ten times the recommended concentration of 0.03 mg/l. Annual average phosphorus concentrations in the Avon River downstream from Stratford (at Station 8, generally collected on a monthly basis) have been reduced by a factor of ten since 1968 (Table 8). Reductions in phosphorus concentrations, especially since 1974, are primarily a result of waste water treatment improvements by the City of Stratford.

Table 6. Water quality data for Avon River, June 19 to 22, 1977.

Parameter	Monitoring Stations													
	1	2	3	4	5	6	STP	7	8	9	10	11	12	13
Total phosphorus as P (mg/l)	0.05	0.04	0.26	0.11	0.10	0.13	0.77	0.23	0.37	0.23	0.16	0.19	0.19	0.20
Soluble phosphorus as P(mg/l)	0.01	0.01	0.02	0.01	0.01	0.01	0.53	0.09	0.26	0.16	0.07	0.09	0.11	0.12
Total kjeldahl nitrogen as N (mg/l)	0.61	0.60	2.26	1.10	1.00	1.10	2.82	1.24	1.72	0.84	0.90	1.17	1.11	1.04
Nirate as N (mg/l)	1.85	1.37	0.46	0.13	0.11	0.08	14.5	3.00	6.10	4.15	3.33	1.90	1.27	0.95
Free ammonia as N (mg/l)	0.06	0.10	0.60	0.15	0.10	0.11	2.1	0.41	0.84	0.06	0.03	0.12	0.10	0.08
Nitrite as N (mg/l)	0.04	0.05	0.06	0.03	0.02	0.02	0.98	0.17	0.42	0.35	0.20	0.14	0.09	0.06
Zinc (mg/l)	--	<0.02	--	--	--	--	--	--	0.07	--	--	--	--	--
Copper (mg/l)	--	<0.01	--	--	--	--	--	--	<0.02	--	--	--	--	--
Chromium (mg/l)	--	<0.02	--	--	--	--	--	--	<0.02	--	--	--	--	--
Temperature	17	19	21	21	22	21	18	19	20	21	21	22	22	22
pH	8.0	8.0	8.3	8.2	8.3	8.2	7.5	7.9	8.0	9.3	9.3	9.2	9.2	9.4
Turbidity (Formazin)	2.6	3.4	6.2	4.7	3.9	4.7	1.9	4.0	2.0	1.9	3.1	4.9	3.4	2.5
Suspended solids (mg/l)	4	8	15	11	7	13	4	7	16	5	8	11	9	6
Chloride (mg/l)	9.8	9.7	28.5	33.9	33.8	33.5	205	88	123	112	106	96.8	95.0	93.0
Minimum dissolved oxygen (mg/l)	5.7	3.8	6.5	6.9	7.0	8.3	6.8	5.5	2.7	1.7	2.1	2.0	3.2	3.5
BOD_5 (mg/l)	1	1	11	5	5	6	4	4	4	2	2	2	3	3
Total organic carbon (mg/l)	2.5	3.3	11.5	7.5	7.4	7.6	10.5	7.8	8.3	7.6	7.8	8.4	8.5	8.6
Total coliform(per 100 ml)	6500	1100	130	330	490	2000	400	4200	1500	900	530	980	870	1200
Fecal coliform (per 100 ml)	1960	640	15	10	20	59	11	180	220	290	150	230	280	410
Fecal streptococcus (per 100 ml)	400	160	40	25	11	31	6	100	180	160	74	130	100	100
<u>Pseudomonas aeruginosa</u> (per 100 ml)	< 4	< 4	< 4	1	< 4	1	1	2	2	1	< 4	< 4	< 4	< 4

Table 7. Water quality data for Avon River, July 18 to 22, 1977.

Parameter	Monitoring Stations													
	1	2	3	4	5	6	STP	7	8	9	10	11	12	13
Total phosphorus as P (mg/l)	0.03	0.04	0.20	0.17	0.10	0.12	0.39	0.17	0.20	0.24	0.20	0.22	0.22	0.21
Soluble phosphorus as P(mg/l)	0.01	0.01	0.01	0.01	0.01	0.01	0.19	0.08	0.14	0.13	0.06	0.08	0.06	0.07
Total kjeldahl nitrogen as N (mg/l)	0.54	0.54	2.39	2.30	1.08	1.27	1.83	1.33	1.16	1.08	1.26	1.39	1.50	1.55
Nitrate as N (mg/l)	1.64	1.16	0.29	0.38	0.57	0.52	12.2	3.51	5.43	4.93	4.15	2.86	3.97	2.77
Free ammonia as N (mg/l)	0.03	0.06	0.51	0.36	0.13	0.22	0.95	0.45	0.37	0.13	0.07	0.18	0.14	0.16
Nitrite as N (mg/l)	0.05	0.05	0.07	0.06	0.06	0.07	1.02	0.27	0.49	0.21	0.09	0.10	0.09	0.08
Zinc (mg/l)	--	<0.02	--	--	--	--	0.34	--	0.05	--	--	--	--	--
Copper (mg/l)	--	<0.01	--	--	--	--	0.02	--	<0.01	--	--	--	--	--
Chromium (mg/l)	--	<0.02	--	--	--	--	0.51	--	0.33	--	--	--	--	--
Temperature (^{o}C)	21	24	27	26	27	25	20	23	25	26	26	27	27	27
pH	8.1	8.2	8.0	7.9	8.2	8.0	5.9	7.7	8.1	8.8	8.8	8.6	8.9	8.7
Turbidity (Formazin)	1.5	2.6	5.0	5.8	4.2	4.1	1.4	4.9	2.4	3.8	6.2	6.1	6.1	8.7
Suspended solids (mg/l)	8	8	8	12	8	9	3	8	7	15	27	24	25	34
Chloride (mg/l)	10.3	10.3	36.9	33.7	34.0	33.8	210	92.5	123	104	107	104	104	101
Minimum dissolved oxygen	4.5	2.7	11.9	4.9	5.6	6.3	8.9	3.6	1.3	2.5	4.6	3.0	3.3	3.2
BOD_5 (mg/l)	1	2	9	10	5	4	4	3	3	3	3	4	4	4
Total organic carbon (mg/l)	6	7	12	12	12	11	11	11	11	10	12	12	14	12
Total coliform (per 100 ml)	2200	1300	650	5900	9400	25000	<140	1900	2700	4700	1700	1500	2100	1600
Fecal coliform (per100 ml)	810	500	39	220	270	530	< 5	< 40	430	2000	1200	610	370	560
Fecal streptococcus (per 100 ml)	320	170	320	180	100	270	< 6	< 90	500	560	270	160	220	240
Pseudomonas aeruginosa (per 100 ml)	<4	< 4	16	<13	<10	<16	< 4	< 7	<24	< 6	< 6	< 6	< 4	< 4

Table 8. Annual average phosphorus concentrations in the Avon River downstream from Stratford at Station 8.

Year	Total phosphorus as P (mg/l)	Soluble phosphorus as P (mg/l)
1968	1.62	0.88
1969	2.01	1.37
1970	1.56	1.19
1971	1.71	1.47
1972	1.14	0.92
1973	1.50	1.19
1974	0.42	0.28
1977	0.31	0.18
1978	0.20	0.11

Ammonia is a nutrient for plants and in the un-ionized form is toxic to fish. The percentage of un-ionized ammonia depends on the pH and temperature of the water. The un-ionized ammonia using average pH, temperature and ammonia values is above the objective of 0.02 mg/l at Station 8. Ammonia levels essential to the protection of aquatic life were exceeded in the June survey at Station 3 and Stations 7 to 13. During the July survey, excessive concentrations were found at stations 3, 4 and 5 above the Stratford sewage treatment plant and at stations 7, 9, 11, 12 and 13 downstream from the sewage plant. Elevated ammonia levels above the Stratford sewage treatment plant were due primarily to industrial discharges to the Burritt Street storm sewer. Downstream from Station 8, the discharge of ammonia from the Stratford sewage treatment plant and high pH levels caused un-ionized ammonia in the lower reaches of the river to be above the water quality objectives. A more detailed summary of ammonia conditions in the Avon River is provided in Table III of the Appendix.

Concentrations of zinc in the Avon River at Station 8 were recorded to be greater than the objective of 0.03 mg/l during both surveys. Also, chromium was recorded to be three times higher than the objective at Station 8 during the July survey. These metals probably originate from industrial discharges to storm sewers and/or the sanitary sewers.

During the June, 1977 survey, dissolved oxygen levels in the Avon River were slightly less than the objective of 4 mg/l at Station 2 upstream from Stratford and more severe reductions occurred downstream from Stratford (Station 8 to 13) where the objective was not met during the June, 1977 survey. At stations 9, 10 and 11, minimum dissolved oxygen levels were about one-half the Ministry's objective. Dissolved oxygen concentrations improved at stations 12 and 13 in the lower reaches of the Avon River where the minimum concentration was greater than 3 mg/l. Conditions during the July survey were similar to the previous survey, with the minimum level occurring at Station 8 (1.3 mg/l). Recovery of dissolved oxygen concentrations in the lower reaches of the Avon River to greater than 3 mg/l was again evident.

Depressed dissolved oxygen conditions in the Avon River downstream from Stratford are caused by night-time respiration of aquatic plant and algae growths in the river, creating adverse effects on fish life. Sunlight, nutrients (primarily phosphorus), a sustained streamflow and rocky substrate in this section provide ideal conditions for luxuriant growths of aquatic plants and algae. In order to document long-term dissolved oxygen conditions a continuous dissolved oxygen and temperature meter was installed at Station 9 in June of 1977. Estimated maximum, minimum and daily averages for dissolved oxygen during the spring to fall period for 1977 and 1978 are depicted in Figure 2. Numerous reductions below the Ministry's objective of 4 mg/l occurred during the late May to September period, with the objective generally being met during other periods for which records were obtained.

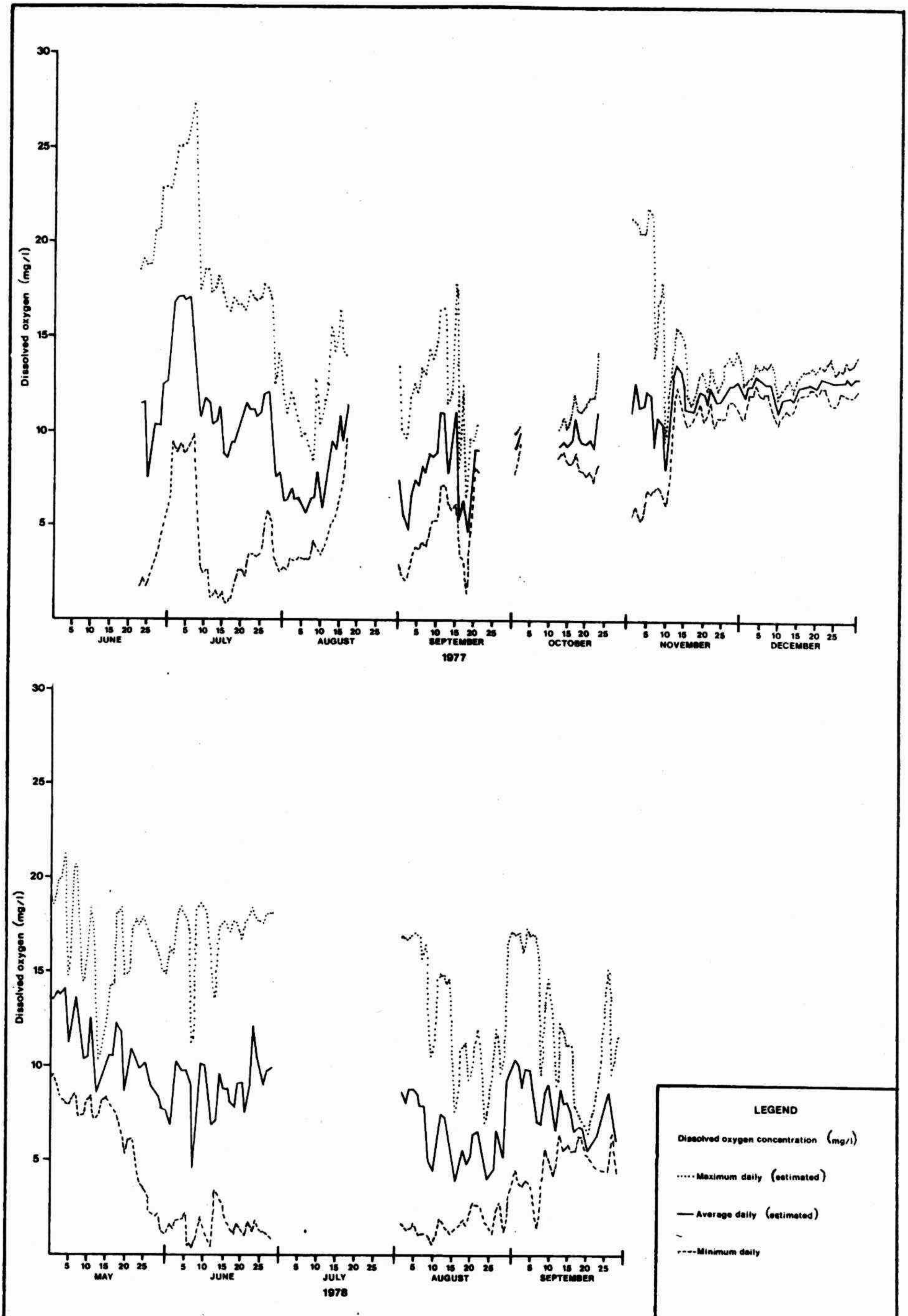

Figure 2. Dissolved oxygen recorded at Station 9 on the Avon River downstream from Stratford.

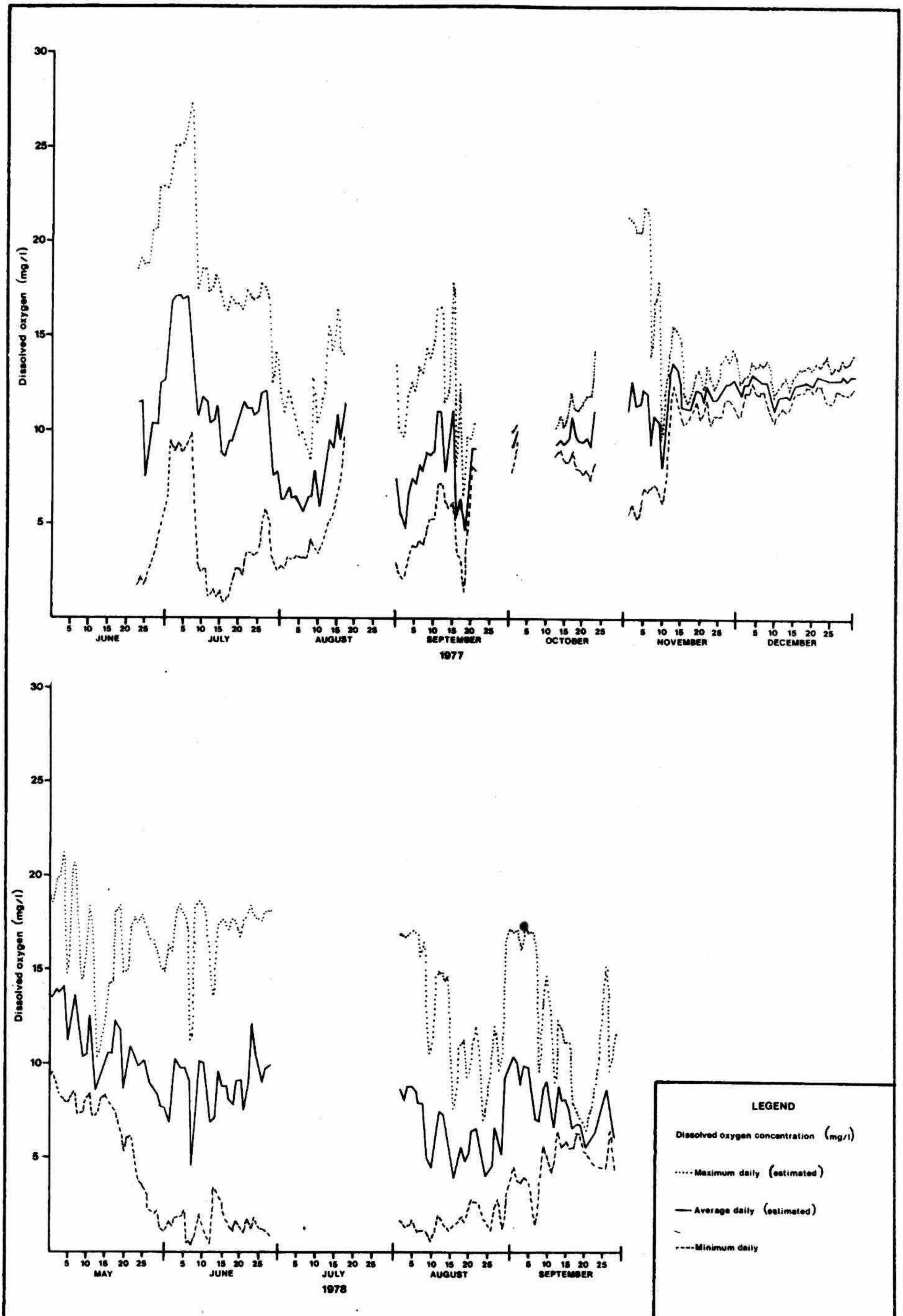

Figure 2. Dissolved oxygen recorded at Station 9 on the Avon River downstream from Stratford.

Bacteriological concentrations exceeded the recommended criteria for livestock watering at all stations sampled on the Avon River. Fecal coliform and fecal streptococcus levels were high at stations 1 and 2, lower through Stratford and increased downstream from Stratford at Stations 8 through 13. It is suspected that these elevated levels were associated primarily with agricultural runoff.

Consideration of chlorine residuals in the Stratford sewage treatment plant effluent relative to daily streamflow (measured from 1964 to 1977) suggest that the chlorine residual concentrations in the Avon River for the May-to-September period were above the level lethal to fish 99 percent of the time, assuming an effluent residual of 0.5 mg/l. A study of the impact of chlorine residuals on the Avon River during July 11 and 12, 1977 showed that lethal concentrations persisted for 500 to 2800 feet downstream from the sewage plant. In general, the chlorine residual had dissipated at Station 8 which is about 4000 feet downstream from the sewage plant.

AQUATIC PLANT BIOMASS

As noted previously, highly favourable conditions have contributed to excessive growths of aquatic plants in the Avon River from Stratford to the North Thames River. In order to document the amount of plant biomass in the river, four survey runs were conducted from June to November, 1977. The densities of aquatic plants are shown in Figure 3 and the types and percentage cover of aquatic plants are given in Table IV in the Appendix. The alga *Cladophora*, moss and pondweed (*Potamogeton* sp.) were the principal types of plants present.

The total amount of biomass in the reach from Stratford to the North Thames River for four periods was estimated using the density of aquatic plant biomass measured in 1977 (Table 9) and by estimating spring biomass production for the Bayfield River in 1978 (a similar watershed) since

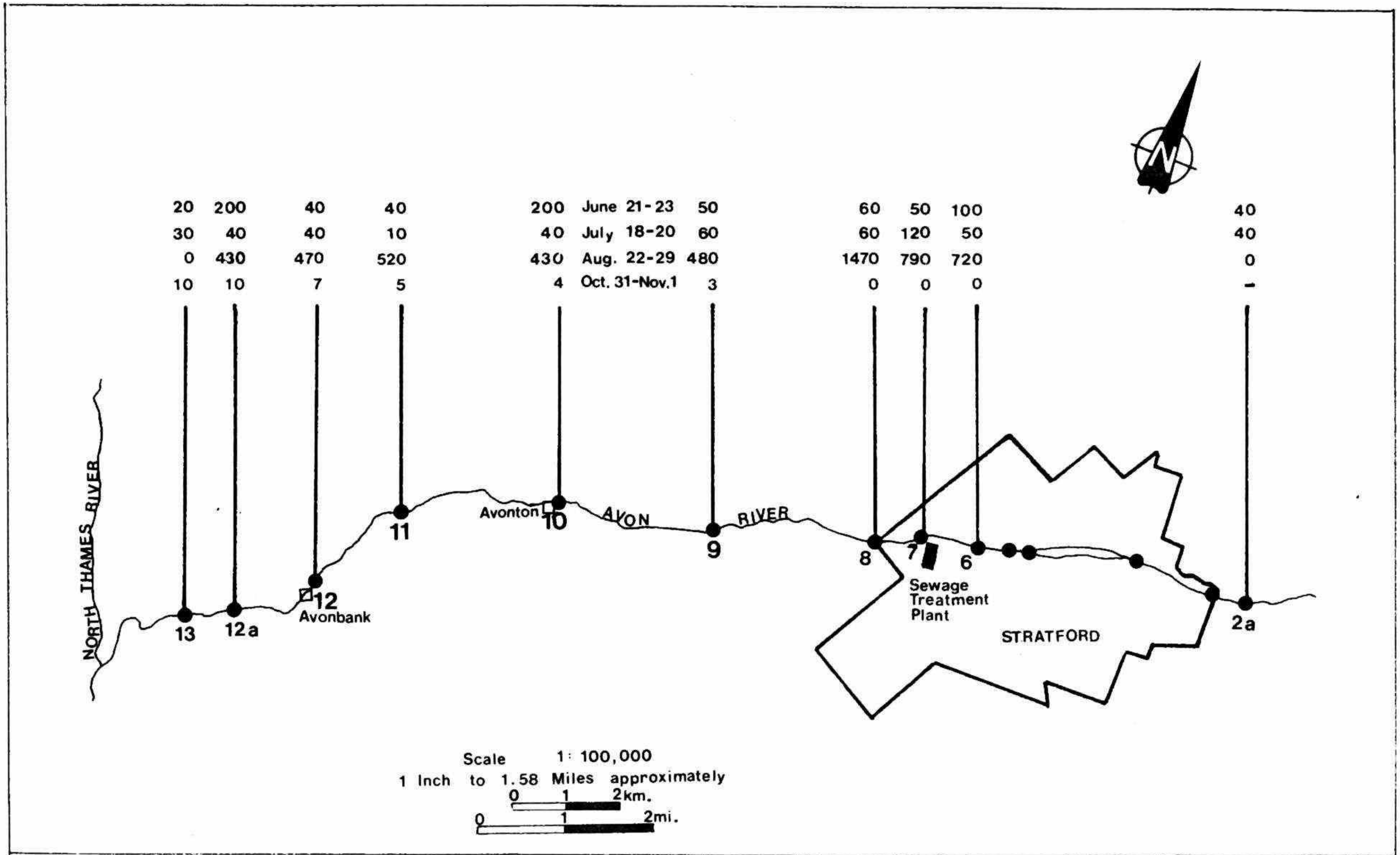

Figure 3. Aquatic plant densities in grams per square metre (dry weight) for stations sampled during four surveys on the Avon River during 1977.

Table 9. Estimated annual aquatic plant biomass production in the Avon River from Stratford to the North Thames River.

Period	Predominant aquatic plants	Plant density 1977 gm dry wt/m^2	Estimated production of plant biomass 1977 kg (lbs)	Estimated production of plant biomass average year kg (lbs)
April to mid-June	Cladophora	560[a]	120,000 (264,500)	120,000 (264,500)
Mid-June to end of July	Cladophora Potamogeton	60	26,000 (57,300)	26,000 (57,300)
August to mid-September	Potamogeton Moss	540	120,000 (264,500)	120,000 (264,500)
Mid-September to November	Cladophora	5	1,000 (2,200)	60,000[b] (132,300)
Dry wt. Total plant biomass (kg)			270,000 (595,200)	330,000 (727,500)

[a] From Bayfield River (spring, 1978)
[b] Estimated - one half of April to mid June biomass production.

Plate 3. Aquatic plant growth on the Avon River at Station 8 downstream from the City of Stratford, 1977.

Plate 4. Dense Cladophora growth on the Avon River near Station 9 downstream from the City of Stratford, 1977.

spring sampling was missed on the Avon River the year before. The production of plant biomass estimated for an average year is 330,000 kg (727,500 lbs) dry weight. Although the biomass assessments are recognized to be based on rough estimation procedures, it is felt that they reasonably reflect the high production of plant growth in this portion of the river.

Applying average respiration rates to the plant biomass estimates, night-time dissolved oxygen demand in the Avon River from Stratford to the North Thames River was estimated during four periods of the year. During the summer the calculated oxygen demand (Table 10) would be as high as 3200 kg/day (7,100 lbs/day), compared with an oxygen demand from the Stratford sewage treatment plant of only about 450 kg/day (1000 lbs/day).

BOTTOM FAUNA

Benthic fauna in the Avon River were assessed in 1959, 1960, 1965, 1971, 1976 and 1977 (Figure 4). This documentation of aquatic insects and other organisms has indicated that more diverse benthic communities and populations exist upstream from Stratford than are present downstream.

Surveys in 1959 and 1960 documented serious degradation of benthic communities downstream from Stratford to the mouth of the Avon River. Intolerant species were almost non-existent and tolerant tubificid worms and true fly larvae (midge and blackfly) dominated the benthos. The 1965 study again documented the virtual absence of intolerant organisms downstream from Stratford and some marginal improvement owing to the dominance of true fly larvae in proportion to tubificids in the benthic communities. More notable improvements in the structure and composition of benthic communities were documented downstream from Stratford during 1971. Species diversity had increased and total numbers of individual organisms had risen dramatically. Recovery of benthic communities downstream from Stratford has progressed

Table 10. Estimated oxygen demand from aquatic plants in the Avon River from Stratford to the North Thames River.

Growth period	Photosynthetic rate (mg O_2/gm dry wt./hr)[a]	Respiration rate (mg O_2/gm dry wt./hr)[b]	Night time oxygen demand (mg O_2/gm dry wt./day)[c]	Total plant biomass kg (lbs)	Total night time oxygen demand kg/day (lbs/day)
May to mid-June	30	3	27	120,000 (264,500)	3,200 (7,100)
Mid-June to end of July	30	3	27	26,000 (57,300)	700 (1,500)
August to mid-September	10	1.5	15	120,000 (264,500)	1,800 (4,000)
Mid-September to October	30	3	30	60,000 (132,300)	1,800 (4,000)

[a] Estimated - Milligrams of oxygen production per gram of biomass (dry weight) per hour.
[b] Estimated - Milligrams of oxygen consumption per gram of biomass (dry weight) per hour.
[c] Estimated - Milligrams of oxygen consumption per gram of biomass (dry weight) per day.

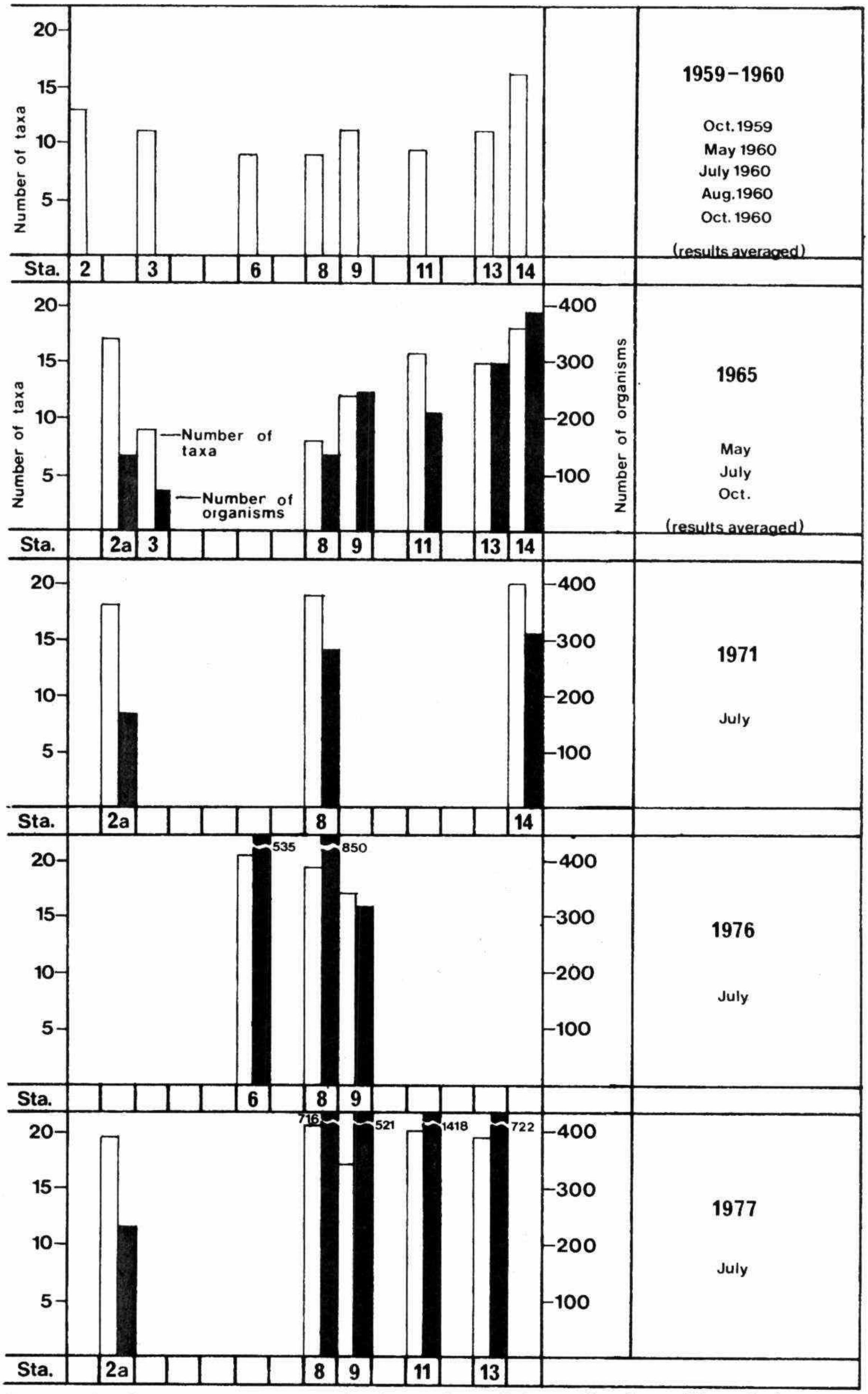

Figure 4. Aquatic macroinvertebrates collected from the Avon River during various stream surveys between 1959 and 1977.

significantly as indicated by the surveys in 1976 and 1977. Intolerant caddisfly larvae, Cheumatopsyche and Hydropsyche, were documented from Station 8 downstream to the mouth of the Avon River, reflecting improved dissolved oxygen conditions and reduced levels of suspended solids. The number of organisms found (an average in excess of 800 organisms per square foot) suggested a nutrient-enriched warm water environment with a somewhat improved oxygen regime and reduced toxic conditions compared to previous survey periods.

FISH INVENTORIES

Inventories of fish populations were carried out by the Ontario Water Resources Commission and the Ministry of the Environment on the Avon River in 1959, 1960, 1965, 1971 and 1977. Fish collections during most sampling periods indicated that "better" fish communities existed upstream from Stratford. In October of 1959 fish were virtually absent in the reach from Stratford downstream to the North Thames River. Sampling in 1960 documented marginal improvements with only a few species present in the downstream reach. Intensive sampling during May, July and October of 1965 documented a stable and diverse fish community upstream from Stratford. Species diversity downstream was still severely disrupted with only marginal recovery near the mouth of the Avon River (Figure 5). The July, 1971 survey indicated definite improvement in fish communities downstream from Stratford (beyond the toxic reach affected by chlorine residual) as numbers of species and total numbers of fish increased throughout the area sampled.

Fish collections in June and November, 1977 indicated fish communities downstream from Stratford were improving further in diversity and in numbers. During the 1977 sampling, two smallmouth bass were collected at each of stations 8 and 13. This is believed to be the first documented appearance of this gamefish in the Avon River in the past 20 years.

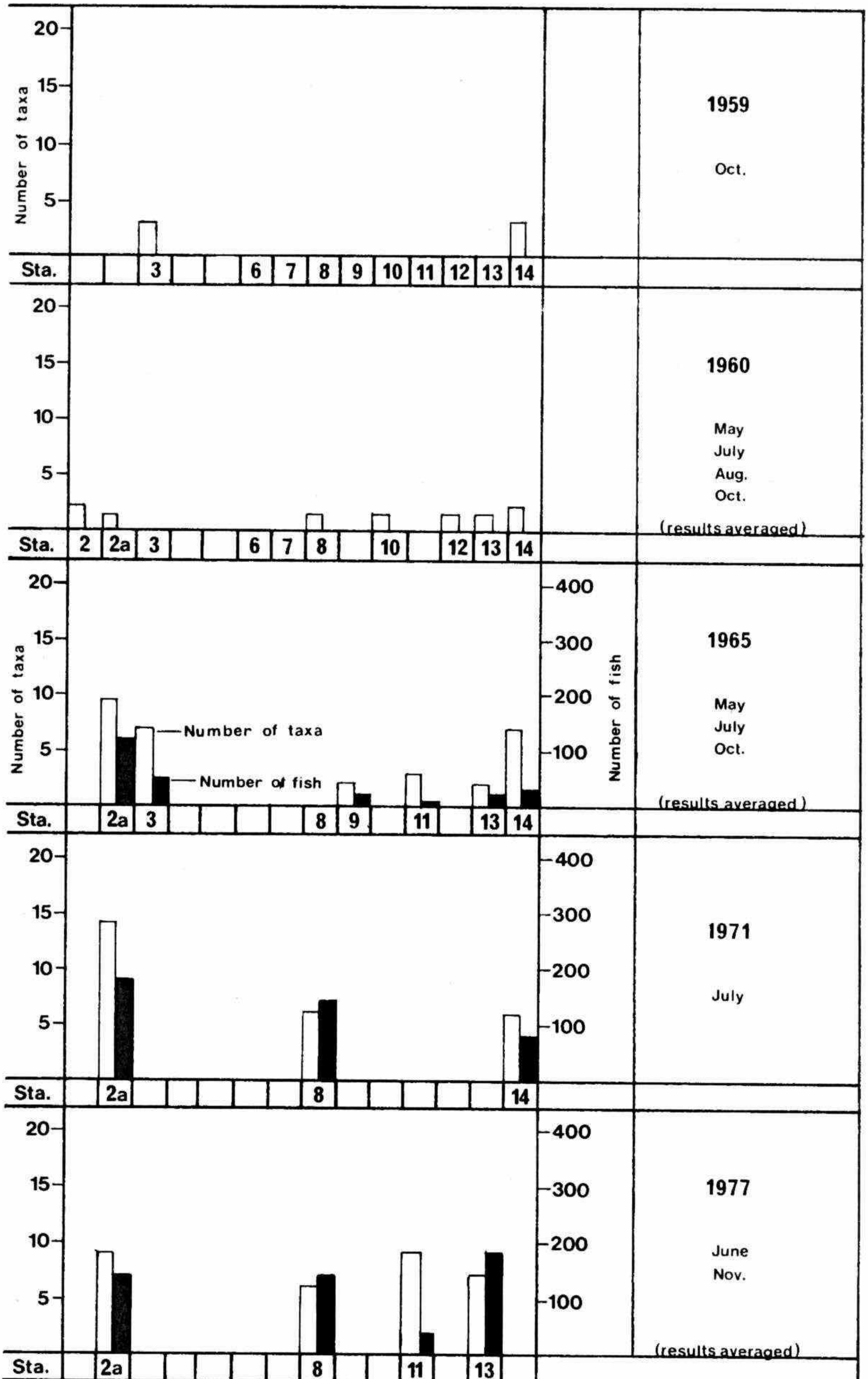

Figure 5. Fish collected from the Avon River during various stream surveys between 1959 and 1977.

This species is common to the North Thames River and its presence would be expected under normal conditions in the Avon River. The 1952 Upper Thames River Conservation Report indicated smallmouth bass to be well distributed throughout the Thames River watershed.

It is evident that fish communities downstream from Stratford are responding positively to improvements made in waste water treatment by the City of Stratford over the past several years.

CONCLUSIONS

1. Phosphorus is considered to be the critical nutrient affecting excessive aquatic plant growths in the Avon River, which fortunately is most amenable to control measures.

2. Agricultural runoff contributes 47 percent of the annual total phosphorus load to the Avon River at Stratford.

3. The Stratford sewage treatment plant contributes 35 percent of the annual total phosphorus load and 59 percent of the soluble phosphorus load to the Avon River watershed above Station 8. Seventy-two percent of the ammonia, 100 percent of the chlorine residual and 92 percent of the measured chromium (substances which are toxic to aquatic life) are contributed by the sewage treatment plant.

4. Industrial discharges to storm sewers in Stratford contributes 22 percent of the ammonia, 50 percent of the copper load and 66 percent of the zinc loading to the Avon River.

5. Storm sewer runoff in Stratford contributes 35 percent of the BOD_5 load to the Avon River and 61 percent of the calculated lead load.

6. The water quality in the Avon River downstream from Stratford did not meet the Ministry of the Environment objectives for dissolved oxygen, ammonia, chlorine residual, zinc and chromium during water quality surveys in 1977. In addition, phosphorus concentrations that would curtail excessive aquatic plant growths were equalled or exceeded at all river monitoring stations and were approximately ten times the recommended level at stations downstream from the Stratford sewage treatment plant. Recommended bacteriological levels for livestock

watering were generally exceeded at all monitoring stations.

7. Excessive nutrients (phosphorus), rocky substrates and available sunlight (lack of shade trees) have produced luxuriant aquatic plant growths from Stratford to the North Thames River. The estimated annual (dry weight) production of aquatic plants in this reach of the Avon River in 1977 was 330,000 kg (727,500 lbs). This plant biomass was the most significant factor promoting daily dissolved oxygen deficiencies in the Avon River during the summer period.

8. Improved pollution control measures in the City of Stratford have resulted in water quality improvements (phosphorus, BOD_5 and ammonia concentrations) and associated improvements in bottom fauna and fish since 1959. Smallmouth bass were found in the Avon River during the 1977 survey for the first time in 20 years.

ACKNOWLEDGEMENTS

The Technical Support Section wishes to acknowledge the assistance of staff from the Municipal and Private Abatement, the Industrial Abatement and the Utility Operations Sections of the Southwestern Region for their assistance in the collection of data during the 1977 surveys and their valuable comments on the draft of this report. Special appreciation is expressed to Mr. Cliff Biggins, Chief Operator of the Stratford sewage treatment plant for his assistance during the surveys and his patience while data were assembled on the by-passing of raw and partially treated sewage. Appreciation is extended to staff of the Water Resources Branch for providing data and information on loadings from non-point sources and for carrying out an assessment of chlorine residual on the Avon River in 1977 with the assistance of the Laboratory Services Branch.

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APPENDIX

Table I	Concentrations and loads of contaminants present in industrial discharges to the City of Stratford storm sewers, June 19 - 22, 1977 and July 18 - 21, 1977.
Table II	Concentrations and loads of heavy metals from June and July, 1977 surveys of the Avon River in the vicinity of Stratford.
Table III	Un-ionized ammonia concentrations greater than the objectives for protection of aquatic life as determined during the June and July, 1977 surveys.
Table IV	Density (as dry weight), types and percentage cover of aquatic plants in the Avon River, 1977.

Table 1. Concentrations and loads of contaminants present in industrial discharges to the City of Stratford storm sewer, June 19 to 22, 1977 and July 18 to 21, 1977.

Industry	Flow m^3/s (cfs)	Concentration mg/l					Load kg/day (lbs./day)				
		Free ammonia as N	Total phosphorus as P	Soluble phosphorus as P	Suspended solids	BOD_5	Free ammonia as N	Total phosphorus as P	Soluble phosphorus as P	Suspended solids	BOD_5
Standard Products (Canada) Ltd.	0.004 (0.16)	0.05	<0.05	<0.05	7.1	5	0.02 (0.04)	<0.02 (<0.04)	<0.02 (<0.04)	2.8 (6.1)	2.0 (4.3)
Korlin Ltd.	0.005 (0.19)	0.9	0.19	<0.05	7.5	6	0.42 (0.92)	0.09 (0.19)	<0.02 (<0.05)	3.5 (7.7)	2.8 (6.2)
Perth Metal Industries Ltd.	0.004 (0.16)	0.1	0.35	0.10	4.0	1	0.04 (0.09)	0.14 (0.30)	0.04 (0.09)	1.6 (3.5)	0.4 (0.9)
Blackstone Industrial Products Ltd.	0.013 (0.46)	14.0	1.1	<0.05	35	37	16 (35)	1.2 (2.7)	0.05 (0.12)	40 (87)	42 (92)
Dominion Chain Co. Ltd.	0.009 (0.33)	12.0	1.0	0.05	36	14	10 (21)	0.81 (1.8)	0.04 (0.09)	29 (64)	11 (25)
Cleaver-Brooks of Canada Ltd.	0.001 (0.027)	0.1	0.25	<0.05	3.1	1	0.005 (0.01)	0.02 (0.04)	<0.005 (<0.01)	0.20 (0.45)	0.07 (0.15)
United[a] Co-operative of Ont.	0.002 (0.06)	0.6	0.12	<0.05	6.7	2	0.09 (0.19)	0.02 (0.04)	<0.01 (<0.02)	1.0 (2.2)	0.30 (0.65)

[a] June survey only

Table I. Continued

Industry	Flow m^3/s (cfs)	Concentration mg/l					Load kg/day (lbs./day)				
		Free ammonia as N	Total phosphorus as P	Soluble phosphorus as P	Suspended solids	BOD_5	Free ammonia as N	Total phosphorus as P	Soluble phosphorus as P	Suspended solids	BOD_5
FAG Bearings Limited	0.01 (0.37)	0.1	0.05	<0.05	2.9	1	0.04 (0.20)	0.05 (0.10)	<0.05 (<0.10)	2.63 (5.79)	0.91 (2.0)
Novatronics of Canada Ltd.	0.001 (0.02)	0.1	0.21	<0.05	2.8	1	0.005 (0.01)	0.01 (0.02)	<0.005 (<0.01)	0.14 (0.30)	0.05 (0.11)
Samsonite of Canada Ltd.	0.002 (0.07)	0.1	0.50	0.05	6.0	1	0.02 (0.04)	0.09 (0.19)	0.01 (0.02)	1.03 (2.27)	0.22 (0.38)
Total							26 (58)	2 (5)	0.15 (0.33)	80 (177)	60 (130)

Table II. Concentrations and loads of heavy metals from the June and July, 1977 surveys of the Avon River in the vicinity of Stratford.

Sample site	Average Flow m^3/s	Average Flow (cfs)	Average Concentrations mg/l Pb	Cu	Cr	Zn	Average Load kg/day (lbs/day) Pb	Cu	Cr	Zn
Station 2	0.084	3.0	<0.03	<0.01	<0.02	<0.02	<0.02 (<0.49)	<0.07 (<0.16)	<0.14 (<0.3)	<0.14 (<0.3)
<u>Storm Sewers</u>										
Devon	0.003	0.11	<0.03	0.02	<0.02	0.04	<0.01 (<0.2)	0.005 (0.01)	<0.005 (<0.01)	0.01 (0.02)
Meier	0.001	0.029	<0.03	0.01	<0.03	0.10	<0.005 (<0.01)	0.001 (0.001)	<0.005 (<0.01)	0.005 (0.01)
Golf course	0.002	0.07	<0.03	0.01	<0.02	0.03	<0.005 (<0.01)	0.002 (0.004)	<0.005 (<0.01)	0.005 (0.01)
Burritt	0.03	1.1	0.12	0.25	0.14	2.5	0.31 (0.69)	0.66 (1.44)	0.37 (0.81)	6.6 (14.4)
Blackstone[a] Industrial Products Ltd.	0.01	0.46	0.09	0.39	0.22	12.1	0.10 (0.22)	0.44 (0.97)	0.25 (0.55)	14.0 (30.1)
Dominion[a] Chain Co. Ltd.	0.01	0.33	0.38	1.16	0.63	7.7	0.31 (0.68)	0.94 (2.07)	0.51 (1.12)	6.2 (13.7)
Hamlet	0.002	0.06	<0.03	0.02	<0.03	0.04	<0.005 (<0.01)	0.003 (0.006)	<0.005 (<0.01)	0.005 (0.01)

[a] Industrial input to Burritt sewer
[b] Flow for June survey only

Table II. Continued

Sample site	Average Flow m^3/s	(cfs)	Average Concentrations mg/l Pb	Cu	Cr	Zn	Average Load (kg/day (lbs./day) Pb	Cu	Cr	Zn
Arch[b]	0.01	0.5	0.02	0.04	0.04	0.30	0.02 (0.05)	0.05 (0.11)	0.05 (0.11)	0.37 (0.81)
Easson[b]	0.01	0.04	<0.03	0.01	<0.02	0.03	<0.005 (<0.01)	0.001 (0.002)	<0.005 (<0.01)	0.003 (0.006)
Huntingdon	0.001	0.03	<0.03	0.02	<0.02	0.02	<0.005 (<0.01)	0.001 (0.003)	<0.005 (<0.01)	0.001 (0.003)
Lorne	0.009	0.33	<0.03	0.02	<0.02	0.22	<0.02 (<0.05)	0.02 (0.04)	<0.02 (<0.04)	0.18 (0.39)
Matilda	0.001	0.01	<0.03	0.02	<0.02	0.05	<0.005 (<0.01)	0.001 (0.001)	<0.005 (<0.01)	0.001 (0.003)
Stratford sewage[c] treatment plant	0.14	4.85	<0.03	0.02	0.51	0.34	<0.36 (<0.8)	0.24 (0.52)	6.11 (13.4)	4.1 (8.9)
Station 8	0.33	11.9	<0.03	<0.02	0.17	0.06	<0.9 (<1.9)	<0.6 (<1.3)	5.0 (10.9)	1.8 (3.9)
Objective			0.025	0.005	0.10	0.030				

[c] Samples for July survey only

Table III. Un-ionized ammonia concentrations greater than the objectives for protection of aquatic life as determined during the June and July, 1977 surveys.

June survey:	Station 3	Station 4	Station 6	Station 7	Station 8	Station 9	Station 10	Station 11	Station 12	Station 13
Number of violations of the 0.02 mg/l objective for un-ionized ammonia	6	0	0	1	5	3	1	4	5	4
Range of concentrations of violations (mg/l un-ionized)	0.028- 0.110	-	-	0.036	0.021- 0.068	0.023- 0.048	0.027	0.033- 0.059	0.021- 0.044	0.021- 0.054
July survey:										
Number of violations of the 0.02 mg/l objective for un-ionized ammonia	3	3	1	1	0	2	0	3	1	2
Range of concentrations of violations for un-ionized ammonia (mg/l)	0.050- 0.085	0.039- 0.044	0.028	0.026	-	0.024- 0.044	-	0.021 0.061	0.033	0.028 0.032

NOTE: Total of 6 samples were obtained during each survey at each station
Un-ionized ammonia concentrations were calculated at 25°C when measured temperatures were in excess of 25°C
Un-ionized ammonia concentrations were calculated at pH 9 when measured pH was in excess of pH 9.

Table IV. Density (as dry weight), types and percent cover of aquatic plants in the Avon River, 1977[a].

Station number	June 21-23, 1977 Density (g/m^2)	June 21-23, 1977 Composition (%)[b]	July 18-20, 1977 Density (g/m^2)	July 18-20, 1977 Composition (%)	Aug. 22-24, 1977 Density (g/m^2)	Aug. 22-24, 1977 Composition (%)	Oct. 31-Nov. 1, 1977 Density (g/m^2)	Oct. 31-Nov. 1, 1977 Composition (%)	Substrate, description
2a	38	60-C	41	80-C	0	0	0	0	cobble <8 cm, isolated rocks 190 cm
6	96	80-C	54	40-C	723	50-C	0	0	cobble 8-16 cm over sand isolated rocks - 30 cm
7	45	75-M	116	25-C 25-M	739	90-M	0	0	cobble 5-8 cm over gravel
8	60	20-C	57	100-C	1467	100-M	0	0	cobble, 8-13 cm over gravel few rocks - 16cm
9	50	95-C 5-P	55	38-C 12-P 50-A	482	80-A 20-P	3	60-A 30-C 10-P	cobble 16-20 cm over gravel
10	196	95-C 5-P	44	75-P	431	95-P	4	90-C	gravel <5 cm, isolated rocks 30 cm
11	36	40-C 5-P 45-A	7	50-P	724	80-P	5	80-C	cobble <13 cm over gravel isolated rocks >30 cm
12	37	25-P 75-A	43	60-P 10-E	470	70-P	7	60-C	cobble <8 cm over gravel
12(b)	204	80-P 20-C	41	80-P	429	87-A 3-C 10-P	10	100-C	cobble <16 cm over gravel

a - C - Cladophora, P - Potamogeton pectinatus, E - Elodea canadensis, M - Moss, A - Periphyton
b - % composition is the % of each plant in relation to stream cover (total % of all species is % cover in the stream).

Table IV. Continued

Station number	June 21-23, 1977		July 18-20, 1977		Aug. 22-24, 1977		Oct. 31-Nov. 1, 1977		Substrate, description
	Density (g/m^2)	Composition (%)[b]	Density (g/m^2)	Composition (%)	Density (g/m^2)	Composition (%)	Density (g/m^2)	Composition (%)	
13	24	100-C	26	60-A 40-C	0	0	12	100-C	cobble <20 cm over gravel isolated rocks >30 cm